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Magnet Division Specification

Superconducting Magnet Division

Specification Number: SMD-APUL-4001

Revision: A

Electrical Testing Procedures – APUL Dipole Magnet Assemblies

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Revision History

- Rev A: Initial Release 8/23/12

1. Scope

The Purpose of this procedure is to effect and document a set of electrical testing procedures used for in-process & acceptance testing of APUL Dipole Magnet Assemblies & Sub-Assemblies. They are intended to be referenced by magnet travelers written to perform those certain segments of APUL magnet fabrication.

2. Associated Documents:

SMD-MAG-1003 Discrepancy Reporting Procedure
SBMS Subject Area “Calibration”

3. Precautions

3.1. The technicians shall be instructed by their cognizant technical supervisor in the operation of the required electrical test equipment and the electrical testing procedures.

3.2. Hipot ("Hypot"), Megger High Voltage Insulation Testing, and Impulse Testing pose an electrical hazard. At least two properly trained technicians must be present to perform this testing. When testing, a trained technician shall be stationed at any point where the item under test is accessible to unauthorized people, and barriers shall be set up. Signs shall be posted reading "DANGER HIGH VOLTAGE" and warning lights shall be turned on.

4. <u>Electrical Resistance Measurement for Collared Individual Coils and Connected Coil Sets.</u>

4.1. Scope: This section describes the method for measuring electrical resistance of a magnet coil, or group of series connected coils, by measuring voltage drops with a 1.0 amp DC current applied through the coil(s).

4.2. Equipment Required:

- Digital multimeters with 0.01 mV (10µV) resolution.
- DC constant current source, 1.0 ampere, isolated from ground.
- Thermometer capable of reading to (0.1°C. @ Room temperature).

4.3. Procedure:

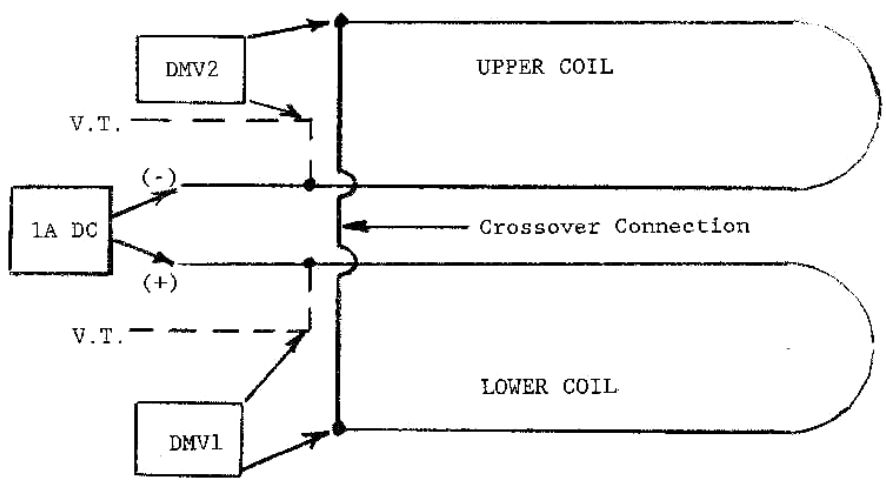
4.3.1. Record coil/magnet temperature in traveler.

4.3.2. Connect the power supply to the two main leads of the series connected coil(s) under test as shown in Figure Below.

4.3.3. Apply a constant current of 1.0 amp DC through the coil.

4.3.4. Record the voltage drops across each coil in the traveler. Typical values for magnet coil(s) are shown below.

Arc Dipole Magnet (8 cm, 9.45 Meter)
a) 1.60 for an individual dipole coil
b) 3.20 for (2) series connected dipole coils



5. Dipole/ Quadrupole Magnet Ratiometer Test

5.1. Scope: This section checks the turn ratio of the coils in dipole magnets. By comparing turn ratios, it is possible to check whether a coil has a shorted turn. The advantage of the method is that it is insensitive to temperature variations.

5.2. Required Equipment:

- BNL Ratiometer And Associated Equipment

Alternate equipment:

- 115V/6.3 VAC, 1 amp, 60 Hz filament transformer
- RMS AC voltmeter, 1 mV resolution on 20 V scale

5.3. Procedure:

5.3.1. Operating Procedure for BNL Ratiometer:

5.3.2. Magnet Connections - Temporarily connect the main coils in series as in the final configuration.

5.3.3. Warm Up - Before any connections are made to the magnet under test or any calibration is attempted, put the function switch in one of the set positions, switch the power on, and allow for a 15-min. warm up.

5.3.4. Place the function switch to the "0.1 SET" position and adjust the "0.1 ADJ." pot until the digital meter (on the "AC Ratiometer") reads "0.1000".

5.3.5. Place the function switch to the "1.0 SET" position and adjust the "1.0 ADJ." pot until the digital meter (on the "AC Ratiometer") reads "1.0000".

5.3.6. Repeat steps 5.3.4 to 5.3.5 until a pot adjustment is no longer necessary to get the respective readings.

5.3.7. With the Function Switch in either of its "SET" positions, connect the output leads of the "AC Ratiometer" (double red and black) across the magnet under test (main leads). Then put the function switch in the "OPERATE" position.

5.3.8. Connect the input lead (single green) of the "AC Ratiometer" to the respective test points 1 thru 3 (common reference) as indicated on the data sheet and read the digital voltmeter and record the value in the respective box on the data sheet.

5.3.9. Calculate the differences between successive readings (Delta 1-2, 2-3, etc.) and record these differences below the boxes marked "Delta 1-2", etc.

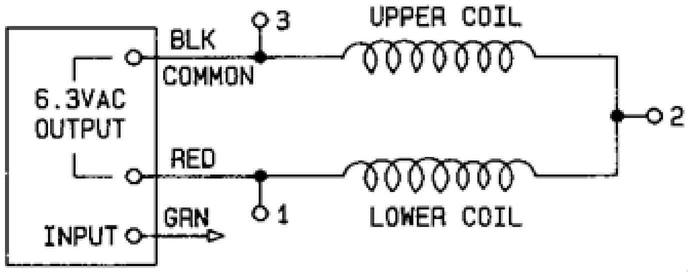
5.3.10. Subtract these calculated difference readings (Delta's) from the ideal values (0.5000) and record the values in the boxes below the boxes marked "Dev". These are coil ratio deviations.

5.3.11. If any of these deviations exceed (0.007 there may be a shorted/wrong coil or improperly connected coil. Notify the Cognizant Engineer.

5.3.12. Finally, add up all of the Delta's and record the sum in the box marked "Total of Delta's". This value should be equal to reading #1, total magnet.

5.3.13. Switch off power and disconnect all leads from the magnet under test.

5.3.14. Operation With Alternate Equipment - The above ratio test may be performed using a 6.3 VAC transformer connected across test points 1 & 3 (common reference) to excite the winding and by measuring the respective RMS AC voltages from test point 3 (common) to test points 1-3 and normalizing the readings by dividing them by the whole magnet voltage reading, 1 to 3. Then enter the normalized readings into the table as described above.



MAGNET NO. ________

+/-.007 MAX. DEV.

			1	2	3
DATE	CK'D BY	REMARKS	WHOLE MAGNET	UPPER HALF	TEST LEADS
		RECORD READINGS 1-3			
			DELTA 1-2	DELTA 2-3	
		CALC DIFFERENCES			
		CALC DEV'S FROM IDEAL 0.5000	DEV	DEV	
			TOTAL OF DELTA'S		

			1	2	3
		RECORD READINGS 1-5			
		CALC DIFFERENCES			
		CALC DEVIATIONS			
		TOTAL OF DELTA'S			
		REMARKS:			

			1	2	3
		RECORD READINGS 1-5			
		CALC DIFFERENCES			
		CALC DEVIATIONS			
		TOTAL OF DELTA'S			
		REMARKS:			

			1	2	3
		RECORD READINGS 1-5			
		CALC DIFFERENCES			
		CALC DEVIATIONS			
		TOTAL OF DELTA'S			
		REMARKS:			

6. Impulse Testing

6.1. Scope: This section is used to determine magnet turn-to-turn coil insulation integrity by stressing the magnet coils with approximately 50-100 Volts between turns. This is done by applying a 2 kV pulse to the coils. The application of this test should not be repeated any more than necessary to avoid over-stressing the insulation. Inductance, Q, and DC resistance tests are normally done before and after the impulse test to confirm that no damage has occurred to the coil(s).

6.2. Material /Equipment:

- Appropriate BNL impulse generator (2 kV max).

6.3. Procedure:

6.3.1. Make certain all the ON-OFF switches are in the OFF position.

6.3.2. Connect the output leads of the "impulse generator" (red & black, checking that black is the ground lead) across the main leads of the magnet coil under test.

6.3.3. Ensure safety barriers are set up and signs are posted and position the ON-OFF switch on the Impulse panel to ON.

6.3.4. Program the tester via the front panel to pulse once at the programming voltage. The minimum voltage is 500 volts, programmed as .5 kilovolts, and the maximum is 5000 volts, programmed as 5 KV. Initialize the tester by pushing manual, then init set. This automatically finds the internal voltage required to impulse at the desired level.

6.3.5. Press “Auto”, and then press “Start”. One test occurs. Push the number 9 and enter to store the waveform.

6.3.6. Repeat steps 6.3.1 to 6.3.5 for any additional coils to be tested, making sure to "select" the new coil name for each test run.

6.3.7. When finished testing, place ON-OFF switches to the OFF position and disconnect all test leads.

6.3.8. Remove any safety barriers and signs.

7. Hypot Testing

7.1. Scope: This section provides a check of the insulation integrity between electrical components in a magnet. During magnet operation, these components may have a large voltage difference between them. This procedure describes the testing of coils or other components with insulation between them. The test determines the insulation integrity by measuring the DC leakage current at the required test voltage between the components. The test voltage is determined by doubling the expected voltage and adding one thousand volts as a conservative protection factor.

7.2. Required Equipment:

- DC Hypot Equipment: Model No. 5205 - Associated Research Inc., Model 944i - Vitrek Inc., or approved instrument (designated as "Hypot").

7.3. Procedure:

7.3.1. Prior to making a hypot test, check that the electrical resistance between components being tested has a minimum value of 20 megohms.

7.3.2. Make sure the power ON-OFF switch is in the OFF position, that the high voltage ON-OFF switch is in the OFF position, and that the voltage control is turned fully counter-clockwise to the zero voltage position.

7.3.3. Connect a grounding cable from the safety ground stud of the "Hypot" to a good electrical ground, and make sure the connection is secure at both ends.

CAUTION

Be sure the "Hypot" is grounded at all times. Failure to observe this caution may result in electrocution.

7.3.4. Connect the return line from the item under test to the Metered Return binding post of the "Hypot" and be sure the grounding switch on the "Hypot" panel is in the Metered Return position.

7.3.5. Connect the High Voltage lead of the "Hypot" to the item under test.

7.3.6. Turn the Microampere Range Switch to the highest range (2000µa). Put the Kilovolt Range switch to Low.

NOTE

The Microampere Range may be changed while the test is in progress

7.3.7. Put the power ON-OFF switch to the ON position and put the HIGH VOLTAGE ON-OFF switch to the ON position.

7.3.8. Rotate the voltage control clockwise until the required voltage is indicated on the Kilovoltmeter or until "arcing" takes place, in which case the voltage control should be rotated counter-clockwise until arcing just stops. (Note: Arcing must be kept to a minimum and must not be allowed to occur more than a few times.) The test voltage shall remain for 60 seconds prior to reading leakage current. If other than the required voltage is used for the test, as above, it must be recorded with the reason why under "Comments" in the traveler.

7.3.9. Read and record the leakage current indicated on the Micrometer. If greater sensitivity is desired for the Micrometer, select a lower range with the Microampere Selector Switch.

7.3.10. After the test is completed, rotate the Voltage control fully counter-clockwise, put the HIGH VOLTAGE OFF-ON switch to the OFF position and put the power ON-OFF switch in the OFF position.

7.3.11. With the "Hypot" still connected to the electrical ground, connect a grounding cable from the "Hypot" safety ground stud to the "Hypot" High Voltage Lead (the clip end, still connected to the test item) for 60 seconds to discharge any stored charge.

7.3.12. Disconnect all "Hypot" leads from the test item.

8. Magnet Coil Inductance & Q Measurements

8.1. Scope: This section describes a method for measuring electrical inductance (L) and Quality Factor (Q) of a coil. This test is used on individual coils or a full series connected magnet to determine if any turn-to-turn shorts exist.

8.2. Equipment Required:

- Hewlett Packard # 4263A RLC Meter or project approved equivalent digital impedance bridge.

8.2.1. Thermometer capable of reading to 0.1°C @ room temperature.

8.2.2. Work bench/coil stands a minimum of 1 ft. from all metallic materials.

8.3. Procedure:

8.3.1. During the following measurements the un-collared coil (in air) should be a minimum of 1 ft. distant from all metallic materials in order to insure accuracy of the readings.

8.3.2. Measure and record coil temperature in the traveler. Using a digital impedance bridge (series mode) connected across the two coil leads, measure and record inductance, L and Quality Factor, Q, of coil at 1.0 KHz test frequency; for a coil in iron use 120 Hz test frequency. Typical values for magnet coil(s) are shown below.

Arc Dipole Magnet (8 cm, 9.45 Meter)
L=6.1 mH, Q=16, @ 1 Khz, single coil in air.
L=9.24 mH, Q=3.3 @ 120 Hz, single coil in iron.
L=28.4 mH, Q=3.8 @ 120 Hz, full series magnet.

9. Megger High Voltage Insulation Test

9.1. Scope: This section provides a check of the insulation integrity between various components in a magnet by measuring megohm resistances with applied voltages up to 1000 volts. Thus, it is a high voltage ohmmeter test usually referred to as a "Megger test". Prior to making a Megger test, check that the electrical resistance between components being tested has a minimum value of 20 mega-ohms.

9.2. Equipment:

- High voltage mega-ohmmeter: AEMC model 1000 or equivalent (designated below as the "Megger").

9.3. Procedure:

9.3.1. Connect a safety ground cable from the magnet yoke/shell/collar and beam tube to a good electrical ground, making sure the connection is secure at both ends. It is essential that this connection be made. At no time should the "Megger" be operated without this safety ground connection.

9.3.2. Before connecting the instrument, make sure that the equipment under test has been discharged and all other test leads are disconnected. BEFORE CONNECTING OR DISCONNECTING THE MEGGER, CHECK TO MAKE SURE THAT THE PUSH-TO-MEASURE BUTTON IS IN THE OFF POSITION. When in this condition, the instrument acts as a voltmeter and gives the operator the opportunity to make sure that the circuit under test is not powered, to rapidly discharge the capacitance of the circuit under test, and to check that the discharge has occurred. (The voltage should be zero.)

9.3.3. Preliminary Check: Without the leads attached to the instrument, proceed as follows: For giga-ohm and mega-ohm ranges: Place the push-to-measure button in the ON position. The pointer should deflect completely to the far right of the scale. The green neon "Bat. lamp" should be lit.

9.3.4. With the instrument in the OFF position, select the desired test voltage and range with the rotary selector switch.

9.3.5. Connect the resistance to be measured between the Earth (+) and Line (-) terminals. At this point, the pointer should not deflect.

9.3.6. Push the push-to-measure button to the ON position for tests of short duration or the LOCK-IN position for tests of long duration. THE GREEN NEON BAT. LAMP SHOULD BE LIT, INDICATING THE PRESENCE OF THE TEST VOLTAGE.

9.3.7. Read directly the insulation resistance on the corresponding scale.

9.3.8. Utilization of the Guard Lead: When making a Megger measurement to ground, connect the "+ Earth" lead to the grounded yoke (shell or collar) and do not use the "- Guard" lead. The component being tested is connected to the "- Line" test lead. When making a Megger measurement between ungrounded components, connect the "- Guard" lead to the grounded yoke (shell or collar). The "+ Earth" and "- Line" leads are connected to the components being tested.

9.3.9. Disconnect all Megger test leads from the test item.

10. High Precision Resistance Insulation Test

10.1. Scope: This section describes the method of using a high precision Giga-Ohmmeter or Digital Volt Meter for low voltage insulation tests. This test is typically used for insulation tests where the component under test cannot withstand a 1kV Megger or hypot test.

10.2. Equipment:

- Suitable 6-1/2 digit Digital Volt Meter. Basic accuracy, 0.005%, DC. Maximum resistance (or O.L. - "Over Load"): 1.0 Giga-ohms or greater. (Typical meter model: HP 3457A or equivalent).

10.3. Procedure:

10.3.1. Turn unit on. Self check OK. All display segments OK.

10.3.2. Select lowest two-wire resistance range.

10.3.3. Short probes together. Verify that meter reads 0 or < 1 Ohm.

10.3.4. Select highest two-wire resistance range.
- Short probes. Verify reading of 0.
- Open circuit probes. Verify O.L. or > 1.0 Gigaohm reading.

10.3.5. Perform OHMS AUTOCAL operation before using extended (Giga-ohm) range.

10.3.6. Select highest two-wire resistance range (or auto).

10.3.7. Momentarily short probes together to verify operation.

10.3.8. Connect probes across circuit to be measured and read resistance value or verify O.L. or > 1.0 Giga-ohm reading. Record resistance in traveler.

10.3.9. Disconnect probes from circuit.

11. Electrical Resistance Measurement for Individual Coils

11.1. Scope: This section describes the method for measuring electrical resistance across a magnet coil by measuring voltage drop with a 1.0 amp DC current applied through the coil.

11.2. Equipment Required:

- Digital Multimeter with 0.01 mV (10µV) resolution.
- DC constant current source, 1.0 ampere, isolated from ground.
- Surface probe thermometer capable of reading to (0.1°C. @ room temperature).

11.3. Procedure:

11.3.1. Record coil temperature with a surface probe thermometer.

11.3.2. Connect the power supply to the two leads of the coil under test. Apply a constant current of 1.0 amp DC through the coil. Record the voltage drop across the coil in the traveler. Typical values for magnet coil(s) are shown below.

11.3.3. Arc Dipole Magnet (8 cm, 9.45 Meter)

- 1.60 for an individual dipole coil
- 3.20 for (2) series connected dipole coils

12. Low Precision Resistance/Continuity/ Insulation Test

12.1. Scope: This section describes the method of using a simple low precision Ohmmeter or Digital Volt Meter for resistance measurement/continuity verification or Megohm insulation tests.

12.2. Equipment:

- Suitable 3-1/2 digit Digital Volt Meter - Basic accuracy, 0.5%, DC Ohms resolution: 1 Ohm or less Maximum resistance (or O.L. - "Over Load") - 20 Megohms or greater (Typical meter models: Fluke 77, Beckman 3010)

12.3. Procedure:

12.3.1. Turn unit on. Self check OK. All display segments OK.

12.3.2. Verify that battery voltage is not low.

12.3.3. Select lowest resistance range.

12.3.4. Short probes together. Verify that meter reads 0 or < 1 Ohm.

12.3.5. Select continuity and short probes to verify beeper (if present).

12.3.6. Select highest resistance range.
- Short probes. Verify reading of 0.
- Open circuit probes. Verify O.L. or > 20 Megohm reading.

12.3.7. Select lowest resistance or continuity range.

12.3.8. Momentarily short probes together to verify operation.

12.3.9. Connect probes across circuit to be measured and read resistance value or listen for beeper indicating continuity. Record resistance in the traveler.

12.3.10. Disconnect probes from circuit.

12.3.11. Select highest resistance range.

12.3.12. Momentarily short probes together to verify operation.

12.3.13. Connect probes across circuit to be measured and read resistance value or verify O.L. or > 20 Megohm reading. Record resistance in the traveler.

12.3.14. Disconnect probes from circuit.

13. Quality Assurance Provisions:

The technician is responsible for notifying the technical supervisor and/or the cognizant engineer of any discrepancies occurring during the performance of this procedure. All discrepancies shall be identified and reported in accordance with SMD-MAG-1003.

Measuring and test equipment used for this procedure shall contain a valid calibration label in accordance with the SBMS Subject Area "Calibration"